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SMALL INFORMATION COSTS, RATIONALLY "IRRATIONAL" EXPECTATIONS, AND THE OPTIMAL GOVERNMENT POLICY

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ABSTRACT

In a imperfectly competitive economy under imperfect information, a private gain from using public information may substantially differ from its social gain. The private gain may be very small, and thus even a small cost of monitoring may effectively prevent the firm from using it. The expectations of the firm become "irrational" in the sense that the firm does not incorporate all available information. Such irrational expectations result in a large loss in social welfare. The divergence of the private gain from the social gain stems from externality in the use of information in a imperfectly competitive economy.

1. INTRODUCTION

Are expectations of economic agents rational? Or, do the agents always incorporate all available information into their expectations? The most conspicuous achievement of the rational expectations "revolution" is to make many economists to answer yes to this question. The change is so sweeping that it is now difficult to find theoretical as well as applied work which is not based on the idea of rational expectations.

Empirical studies on expectations, however, reveal the discrepancy between the economist's version of rational expectations and the actual expectations of the public. Many studies using survey data find that people do not seem to use information efficiently, nor use all available information (see Pesando (1975), Friedman (1980), and Lovell (1986)). A different example of "irrational" expectations is those about money supply. Information about money supply is readily available (though it contains substantial errors). Because the welfare of economic agents depends only on real variables, the changes in money supply which can be detected from available information should be neutral. However, many empirical studies show that such changes have real effects (see Bean (1984), Boschen (1985), and Frydman and Rappoport (1987)).

The reaction to this puzzle is so far to maintain the rational expectations hypothesis, but to change the model so as to downplay the role of expectations. Real business cycle theories simply disapprove the importance of money in business cycles. Menu-costs approaches postulate costs of changing nominal variables, so that money is not neutral even under rational expectations.

This paper, however, investigates the plausibility of the economist's version of the rational expectations hypothesis. I argue that the private gain from using public information such as announced money supply figures is likely to be small in a imperfectly competitive economy, especially under near constant marginal cost. Even a small cost of monitoring and assessing such information may be sufficient to prevent firms from using the information. Thus in a economy with non-trivial information costs, firms may rationally choose to be "irrational" in their expectation formation in the sense that they do not use all available information. On the contrary, the social gain from using public information is much larger than the private gain. This is because of externality in the use of information in a imperfectly competitive economy, which is related to aggregate demand externality (Blanchard and Kiyotaki (1987) and Akerlof and Yellen (1985)).

The plan of this paper is as follows. In order to highlight the main argument, I choose as a starting point the Phelps-Lucas information island model, which has been extensively investigated in the last decade. I incorporate monopolistic competition into this framework in Section 2. The major results are obtained in Section 3, under the assumptions of (a) no utility from real money balances and (b) noiseless monetary information. I show that (1) if marginal cost of production is close to be constant, the private gain from using public information is quite small compared with its social gain, but (2) if competition among firms is sufficiently strong, the two gains are almost the same. The implications for the government policy are also investigated in Section 3. The assumptions (a) and (b) are relaxed in Section 4. There the results of Section 3 are shown to hold true in a more general framework. Section 5 analyzes a perfectly competitive case, and shows that the private gain is sufficiently large. Thus the result obtained in this paper is not a result of imperfect information *per se* but the result of monopolistic competition. Section 6 concludes the paper.

2. A MODEL OF MONOPOLISTIC COMPETITION UNDER IMPERFECT INFORMATION

Consider an economy with a continuum of firms, each producing a specific product that is a imperfect substitute for other products. As a result, firms have some monopoly power with price-taking consumers in product markets, though they cannot influence aggregate variables. Consumer-workers in the economy are identical, selling labor to each firm and receiving a share of each firm's profits as dividends. The representative consumer has CES preference over differentiated products, and Cobb-Douglas preference over (aggregate) consumption and real money balances. Firms and workers are in a bilateral monopoly in the labor market, so that firms maximize the real joint benefit of themselves and their workers, which is equal to the representative consumer's utility under our assumption. The model is described in details in Nishimura (1988) and summarized in Table 1. In the following analysis, I consider the corresponding reduced-form model. Hereafter a lower case variable denotes the logarithm of the upper case one. For example, $x = \log X$.

In the symmetric equilibrium of this economy, the aggregate demand $\bar{y}$ is determined by real balances:

$$(1) \qquad \bar{y} = h_1 + m - \bar{p}, \text{ where } h_1 = \log\{\zeta/(1 - \zeta)\},$$

where m is money supply, $\bar{p}$ the price level, and ζ a parameter in utility. This aggregate demand $\bar{y}$ is distributed among firms in the following way:

$$(2) \quad q_u = - k(p_u - \bar{p}) + \bar{y} + u = - k(p_u - \bar{p}) - \bar{p} + \alpha, \text{ where } \alpha \equiv h_1 + m + u,$$

where q_u and p_u are the demand for and the price of the product of type u. The disturbances m and u are normally distributed and satisfy Em = Eu = Emu = 0, $Em^2 = \sigma_m^2$, and $Eu^2 = \sigma_u^2$. The price level $\bar{p}$ is equal to

$$(3) \qquad \bar{p} = \bar{p}_u - z(\rho), \text{ where } \bar{p}_u \equiv \int_{u=-\infty}^{u=+\infty} p_u f(u)du,$$

$\rho \equiv (p_u - \bar{p}_u)/u$, and $z(\rho) \equiv [\{1-(k-1)\rho\}^2/\{2(k-1)\}]\sigma_u^2$. Note that (the log of) the price level for a CES utility function differs from (the log of) the geometric average of individual prices. The term $z(\rho)$ represents necessary adjustment, linking (the log of) the price level, $\bar{p}$, to (the log of) the geometric average of prices, $\bar{p}_u$. This term shows the effect of the dispersion of relative prices on the overall price level.[1]

The firm's objective is to maximize the real joint benefit of itself and its workers, which is in the symmetric equilibrium equal to

$$(4) \qquad \Upsilon = \exp[p_u - \bar{p}]\exp[q_u] - \exp[(1 + c_1)q_u],$$

where the first term is real revenue and the second is the disutility of labor. Here $c_1 = (\mu/\phi) - 1 > 0$, in which ϕ is the elasticity of output to labor input, and μ is the elasticity of disutility of labor.

Following the literature of imperfect-information macroeconomics, I assume that firms are informationally separated from one another. The firm cannot observe $\bar{p}$ as well as m and u in determining its price p_u. However, it has information about the individual demand condition α. The firm forms rational expectations about $\bar{p}$ based on α. The firm's problem is to maximize $\hat{E}\,\Upsilon$ with respect to p_u, where $\hat{E}$ is the expectation operator with respect to the firm's subjective distribution of $\bar{p}$.

The optimal price formula is then

$$(5)\qquad p_u = \frac{1}{1+c_1k}a + \frac{c_1}{1+c_1k}\alpha + \{1 - \frac{c_1}{1+c_1k}\}e(\bar{p}|\Omega), \text{ where}$$

$$a = \log(1+c_1) + \log\frac{k}{k-1} + \omega V(\bar{p}|\Omega) \text{ and } \omega = \frac{1}{2}\{1 + c_1(k-1)\}\{(c_1+2)(k-1) - 1\}.$$

Here $e(\bar{p}|\Omega)$ and $V(\bar{p}|\Omega)$ are, respectively, the linear least squares regression of $\bar{p}$ on available information Ω and its error variance.

Equilibrium Price Level

As a frame of reference, I first present the case of complete information. Let $\bar{p}^*$ be the equilibrium price level in the complete information case. In the complete information case we have $e(\bar{p}^*|\Omega) = \bar{p}^*$ and $V(\bar{p}^*|\Omega) = 0$. Then it is straightforward to show that

$$(6)\qquad \rho = \rho^* \text{ and } \bar{p}^* = \frac{1}{c_1}a^* + h_1 - \frac{1+c_1k}{c_1}z(\rho^*) + m, \text{ where}$$

$$(7)\qquad a^* = \log\frac{k}{k-1} + \log(1+c_1), \text{ and } \rho^* = \frac{c_1}{1 + c_1k}.$$

Under incomplete information, the firm has to form expectations about $\bar{p}$. Note that from the definition of α, we obtain

$$(8)\qquad e(m|\alpha) = \theta(\alpha - h_1), \text{ and } V(m|\alpha) = \theta\sigma_u^2, \text{ where } \theta = \sigma_m^2/(\sigma_m^2 + \sigma_u^2).$$

Then using the undetermined coefficient method (see APPENDIX), we can show that the symmetric equilibrium is characterized by

(9) $\rho = \rho_\theta$ and $\bar{p} = \frac{1}{c_1}a^* + \frac{1}{c_1}\omega V(\bar{p}|\Omega) + h_1 - \frac{1+c_1k}{c_1}z(\rho_\theta) + \delta_\theta m$, where

(10) $V(\bar{p}|\Omega) = \delta_\theta{}^2\theta\sigma_u{}^2$, $\rho_\theta = \dfrac{c_1}{1 + c_1k - \{1 + c_1(k - 1)\}\theta}$ and $\delta_\theta = \rho_\theta$.

Comparison of the above two price levels reveals the following difference due to incomplete information. First, as expected, the sensitivity of the price level to the macroeconomic shock m is smaller under incomplete information than under complete information ($\delta_\theta < 1$) (rigidity of the price level). Second, on the contrary, the relative price ($p_u - \bar{p}_u$) is more sensitive to the microeconomic shock u, and thus more dispersed, under incomplete information than under complete information ($\rho^* < \rho_\theta$) (excessive sensitivity of the relative price). Third, while the sensitivity of the relative price to u is different from the sensitivity of the price level $\bar{p}$ to m ($\rho^* < 1$) under complete information, they are the same ($\rho_\theta = \delta_\theta$) under incomplete information.

Under incomplete information the only information the firm has is its local demand condition, which is the composite of the firm-specific disturbance and the macroeconomic disturbance. Thus the firm's price responds to both disturbances in the same way ($\rho_\theta = \delta_\theta$). Moreover, the local-global confusion due to this sort of imperfect information makes the firm's estimate of the price level insensitive to the macroeconomic shock and sensitive to the microeconomic shock. Consequently the price level becomes rigid to the macroeconomic shock ($\delta_\theta < \delta^*$) and the relative price is more sensitive to the microeconomic shock ($\rho_\theta > \rho^*$) under incomplete information than under complete information.

<u>Social Welfare and Private Benefits</u>

The representative consumer's utility in the symmetric equilibrium is

$$(11)\quad \Psi = \bar{Y} + \frac{M}{\bar{P}} - (\bar{Y})^{1+c_1}\cdot\exp[\Gamma(\rho)] = \exp[\bar{y} + m - \bar{p}] - \exp[(1+c_1)\bar{y} + \Gamma(\rho)].$$

The first two terms are utility from aggregate consumption and real balances. Because the assumed utility function is linear homogeneous in consumption and real balances, Ψ is linear in aggregate consumption and real balances. The third term is the aggregate disutility of labor. Because the level of labor inputs is different among firms reflecting the difference in firm-specific disturbances, the aggregate disutility of labor depends not only the average production level $\bar{y}$ but also the dispersion of labor inputs among firms. The latter is represented by the term $\Gamma(\rho)$. The term $\Gamma(\rho)$ is defined as

$$(12)\quad \Gamma(\rho) = (1/2)[(1+c_1)^2(1 - k\rho)^2 - \{k/(k - 1)\}(1+c_1)\{1 - (k - 1)\rho\}^2]\sigma_u^2,$$

which shows the effect of the dispersion of relative prices on the disutility of labor through the dispersion of labor demand.[2]

The relevant measure of social welfare in this model is the ex post average utility of the representative consumer, W, such as $W = E\Psi$, where E is the expectation operator with respect to m.

On the one hand, the complete information social welfare W^* is from (1) and (6)

$$(13)\quad W^* = \frac{1}{\zeta}\exp[\bar{\bar{y}}^*] - \exp[(1+c_1)\bar{\bar{y}}^* + \Gamma(\rho^*)] \text{ where } \bar{\bar{y}}^* = -\frac{1}{c_1}a^* + \frac{1+c_1k}{c_1}z(\rho^*),$$

because $M/\bar{P} = \{\varsigma/(1-\varsigma)\}\bar{Y}$ in equilibrium. On the other hand, the incomplete information social welfare W is from (1) and (9),

$$(14) \qquad W = \frac{1}{\varsigma}\exp[\bar{\bar{y}} + \frac{1}{2}V(\bar{y})] - \exp[(1+c_1)\bar{\bar{y}} + \frac{1}{2}(1+c_1)^2V(\bar{y}) + \Gamma(\rho_\theta)],$$

where $\bar{\bar{y}} = -\frac{1}{c_1}a^* - \frac{1}{c_1}\omega\delta_\theta{}^2\theta\sigma_u{}^2 + \frac{1+c_1k}{c_1}z(\rho_\theta)$, and $V(\bar{y}) = (1-\delta_\theta)^2\sigma_m{}^2$,

because $\log E\bar{Y} = E\log\bar{Y} + (1/2)V(\log\bar{Y})$ from the log-normality of the random variable $\bar{Y}$.

Next, the appropriate criterion for the firm is the ex post average real joint benefit of itself and its workers, R, such as

$$R = E\ \Upsilon = E\ \{\exp[p_u - \bar{p}]\exp[q_u] - \exp[(1+c_1)q_u]\}.$$

Here E is taken with respect to m and u. In the complete information case, it can be shown with some calculation that the ex post average real benefit R^* is

$$(15) \qquad R^* = \exp[\bar{\bar{y}}^*] - \exp[(1+c_1)\bar{\bar{y}}^* + \Gamma(\rho^*)],$$

while the incomplete information real benefit R is

$$(16) \qquad R = \exp[\bar{\bar{y}} + \frac{1}{2}V(\bar{y})] - \exp[(1+c_1)\bar{\bar{y}} + \frac{1}{2}(1+c_1)^2V(\bar{y}) + \Gamma(\rho_\theta)].$$

3. INFORMATION COSTS AND RATIONALLY "IRRATIONAL" EXPECTATIONS

Suppose that in the incomplete information economy, perfect information about m is now available for all firms. In this section I compare social gain from using this noiseless public information with corresponding private gain. The social gain is an increase in social welfare when all firms use this information. The private gain is an increase in the firm's real benefit, when (1) this firm uses the information but (2) other firms ignore the information. I analyze the two gains under the assumption of $\zeta = 1$. In this case, we obtain $W^* = R^*$ and $W = R$. In the next section the assumptions of (a) noiseless information and (b) $\zeta = 1$ are relaxed.

When the firm uses this macroeconomic information, there is no uncertainty and this case is reduced to the complete information one. Then the normalized social gain from using the information, SG, is

$$(17) \qquad SG = \frac{W^* - W}{W}.$$

Incomplete information reduces social welfare in two ways. First, local-global confusion makes the price level $\bar{p}$ insensitive to the disturbance in money supply and allows money to affect output. The resulting fluctuations of output reduce welfare if marginal cost is increasing.[3] Second, local-global confusion also makes the relative price $p_u - \bar{p}_u$ excessively sensitive to the microeconomic real disturbance. The excessive sensitivity has two welfare reducing effects. On the one hand, the excessive variability of the relative price increases the variability of labor demand, and ultimately, the aggregate disutility of labor if marginal cost is increasing. On the other hand, the excessive variability of the relative price implies the excessive variability of consumption of individual products, which directly reduces the consumer's utility. In our model, this reduction in welfare is represented by an increase in the price level $\bar{p}$. An increase in ρ decreases $z(\rho)$,[4] which raises the price level $\bar{p}$. Thus for a given level of money supply, the consumer's utility is reduced.

Next, consider the private gain from using the information. In this case $\bar{p}$ in (9) is still the actual price level. Because the macroeconomic information resolves uncertainty, the firm's optimal price formula in this case is

$$(18)\quad p_u = \frac{1}{1+c_1k}a^* + \frac{c_1}{1+c_1k}\alpha + \{1-\frac{c_1}{1+c_1k}\}\{\frac{1}{c_1}a^* + \frac{1}{c_1}\omega\delta_\theta{}^2\theta\sigma_u{}^2 + h_1 - \frac{1+c_1k}{c_1}z(\rho_\theta) + \delta_\theta m\}.$$

Inserting this, (3), and (2) into (16), we obtain the ex post average real joint benefit in this case such as

$$(19)\qquad \hat{R} = \exp[\hat{y}(1) + \frac{1}{2}\hat{V}(1)] - \exp[(1+c_1)\hat{y}(2) + \frac{1}{2}(1+c_1)^2\hat{V}(2) + \Gamma(\rho_\theta)],$$

where $\hat{y}(1) = \bar{\bar{y}} + \frac{k-1}{1+c_1k}\omega\delta_\theta{}^2\theta\sigma_u{}^2 + \frac{1}{2}\Phi(c_1, k, \theta)\sigma_u{}^2$, $\hat{V}(1) = \{\frac{1+c_1}{1+c_1k}(1-\delta_\theta)\}^2\sigma_m{}^2$,

$$\hat{y}(2) = \bar{\bar{y}} + \frac{k}{1+c_1k}\omega\delta_\theta{}^2\theta\sigma_u{}^2 + \frac{1}{2}\Xi(c_1, k, \theta)\sigma_u{}^2, \text{ and } \hat{V}(2) = \{\frac{1-\delta_\theta}{1+c_1k}\}^2\sigma_m{}^2,$$

in which $\Phi(c_1, k, \theta) = [(\frac{1+c_1}{1+c_1k})^2 - (\frac{1+c_1-\{1+c_1(k-1)\}\theta}{1+c_1k-\{1+c_1(k-1)\}\theta})^2]$ and

$$\Xi(c_1, k, \theta) = \frac{1}{1+c_1}[(\frac{1}{1+c_1k})^2 - (\frac{1-\{1+c_1(k-1)\}\theta}{1+c_1k-\{1+c_1(k-1)\}\theta})^2].$$

Consequently the normalized private gain from using the information, PG, is

(20) $$PG = \frac{\hat{R} - R}{R} = \frac{\hat{R} - W}{W}.$$

It is evident from the above analysis that the private gain and the social gain are in general different. Moreover, numerical analysis shows that the social gain exceeds the private gain in most cases.

The discrepancy between the private gain and the social one can be explained in terms of externality in the use of information under imperfect competition. Recall that the private gain is an increase in R due to the use of public information, when other firms do not use the information. If other firms do not use the information, the price level $\bar{p}$ is insensitive to m, so that the firm does not gain very much from obtaining accurate information about m. Then the private gain from using public information is small. However, if other firms use the information, the price level becomes sensitive to m. In this case the gain is likely to be substantial. Moreover, the relative price also becomes less excessively sensitive to u, which increases the utility of the consumer. Because the social gain is the welfare gain when all firms use the information, the social gain is larger than the private gain.

The above argument crucially depends on the fact that one firm's gain from using public information is determined by other firms' choice as to whether to use the information. This can be called externality in the use of information in a monopolistically competitive economy. This informational externality is closely related to aggregate demand externality. In a monopolistically competitive economy output is too low because firms have no private incentive to reduce their prices though simultaneous price reduction is socially desirable. This discrepancy between the private gain and the social gain from price reduction is caused by the dependence of one firm's profits on other firms' prices (the price level) through the real balance effect on aggregate demand. A similar dependence also plays a crucial role in making the private gain from using public information and its social counterpart diverge from each other.

In the following I presents two examples, which illustrate the factors determining the discrepancy between the private gain and the social one. In the first example, the private gain from using public information is negligible, though there exists a non-negligible social gain. Thus the ratio of the social gain to the private one is very large. This is the case in which marginal cost is close to be constant. On the contrary, in the second example, the private gain and the social gain are almost the same, so that the ratio is close to unity. This is the case if competition among firms is sufficiently strong.

Marginal Cost

Note that $c_1 = (\mu/\phi) - 1$. Thus a small c_1 implies near-constant marginal cost. If c_1 is close to zero, then the price level is almost completely insensitive to m (see (9) and (10)). Then the private gain from using public information about m is negligible. However, the loss in social welfare is substantial. Note that the incomplete information $\bar{p}$ is substantially higher than the complete information $\bar{p}$, even if c_1 is close to zero. Thus the excessive sensitivity of the relative price reduces utility from consumption and reduces social welfare, although the loss due to fluctuations in the aggregate output as well as individual production becomes negligible as c_1 approaches zero. Thus the social gain is non-negligible. In APPENDIX it is shown that

(21) $\lim_{c_1 \to 0} SG = \exp[\frac{1}{2}\sigma_m^2] - 1 > 0$, and $\lim_{c_1 \to 0} PG = \frac{1 - \exp[-a^*]}{1 - \exp[-a^*]} - 1 = 0.$

Competition

In this differentiated-product model, the appropriate measure of competition among firms is the degree of substitution among their products, k. When competition is intensified, forecast errors imply a large loss in the firm's real benefits because small price difference brings about a large-scale movement of customers and thus a large fluctuation in output. This implies a large expected cost so long as marginal cost is increasing. Since public macro information enables the firm to forecast the price level correctly, the private gain from using such information is very large under strong competition from other firms. Thus the private gain has its maximum value, which is equal to the social gain in most cases, if the degree of competition goes to infinity. APPENDIX shows that

(22) $\lim_{k \to \infty} \hat{R} = \lim_{k \to \infty} \tilde{W}^* > \lim_{k \to \infty} W$, which implies $\lim_{k \to \infty} PG = \lim_{k \to \infty} SG > 0.$

Information Costs and Rationally "Irrational" Expectations

The result of this section shows that if (1) marginal cost is not rapidly increasing and (2) competition is not strong, the private gain from using public information is small. Thus even a small cost of monitoring and assessing public information is likely to prevent the firm from using public information. However, the social gain from using public information is still non-negligible, and much larger than the private gain. Thus the ratio of the social gain to the private gain

(23) $SG/PG = (W^* - W)/(\hat{R} - R).$

approaches infinity, when $c_1 \to 0$. The market economy clearly fails to use information efficiently if both c_1 and k are small.

The recent empirical studies incorporating bilateral monopoly relations in labor markets and imperfect competition in product markets suggest that c_1 and k are in fact small. For example, Bils (1987) estimates the elasticity of marginal labor cost assuming the short-run bilateral monopoly relation (labor as a quasi-fixed factor). His estimate is about 0.24.[5] Thus if $\phi = 1$,[6] then his estimate implies $c_1 = 0.24$. The term k is equal to the own-price elasticity of demand for the firm's products, so that the ratio of the price to marginal cost is equal to $k/(k - 1)$. Hall (1986) estimates the ratio, and finds that it is about 1.6 for both non-durables and durables in manufacturing. This figure implies $k = 2.67$.

Table 2 shows the private gain (PG) and its ratio to the social gain (SG/PG) under the above set of parameters. I consider two cases ($\sigma_m = 0.05$ and 0.2) for the standard deviation of the monetary disturbance, and three cases ($\sigma_u = (1/2)\sigma_m$, σ_m and $5\sigma_m$) for the standard deviation of the firm-specific demand disturbance.

This table reveals that the private gain is very small but the social gain is substantial. For example, in the case that $\sigma_m = 0.05$ and $\sigma_u = 5\sigma_m$, the private gain is only one hundredth of one percent of the firm's incomplete-information real benefit. However, the social gain is ten times larger than the private gain.

The foregoing discussion suggests the possibility that the firm rationally chooses "irrational" expectations, in which it ignores some of available information. Suppose that all firms know the deterministic trend of money supply, but that they do not monitor the announcement of money supply in each period because of the information cost. Then the expected money supply (which is normalized to be zero in this model) is the trend, and the unexpected money supply (which is denoted by m) is the deviation from the trend. Because the past history of money supply is readily available and such information improves the forecast, their expectations are "irrational" in the usual sense. However, the firm is likely to choose to be irrational because the benefit of being rational is smaller than its cost under imperfect competition. Then seemingly irrational expectations found in many empirical studies of monetary non-neutrality may in fact be rational under small information costs. The "anticipated" money in these models may be unanticipated by firms. However, because the social cost of such "irrationality" is significant, as manifested in large fluctuations of output, some kind of intervention may be called for.

The Optimal Policy

The optimal policy of the government is straightforward in this case. Because information about m is accurate, the government can completely stabilize money supply, by offsetting m through its transfer of money to the consumer.[7] This eliminates macroeconomic uncertainty and fluctuations, so that the resulting level of welfare is the same (except for information costs) as in the case in which all firms use public macro information. Consequently, even if all firms are willing to incur information costs, monetary policy is superior to simple information provision, because it saves information costs.[8]

4. EXTENSION

In the previous section, I have compared the private and social gain from using public macro information under the extreme assumptions of (1) no contribution of real balances to utility and (2) noiseless public information. In this section, I relax these assumptions, and analyze the consequence.

Contribution of Real Balances to Social Welfare

The social welfare (in real money terms) (11) implies that the services of real balances contribute to the representative consumer's utility. Note that the price level is lower under complete information than under incomplete information. Thus for a given level of aggregate income and real balances, the difference between the complete information social welfare and the incomplete information social welfare is larger if the utility from the services of real balances is explicitly considered.

On the contrary, the private gain does not include the effect of real balances, thus it is unaffected. Consequently, the ratio of the social gain to the private gain is larger. Moreover, the smaller ζ is, the larger the difference is. Thus the real balance effect strengthens the argument in the previous section that the private gain from using macro information is significantly smaller than its social cost.

Effect of Noise in Public Macro Information

The noise in public information reduces both the social and private gains from using public information. However, the effect of the noise on the social gain is qualitatively different from that on the private gain. The availability of noisy public information may result in a negative social gain (a reduction in social welfare), while it always yields a positive private gain (an increase in the private benefit).

Suppose that public macro information has the following form:

$$(24) \qquad \gamma = m + s,$$

where s is a normally distributed noise satisfying $Es = Ems = Eus = 0$ and $Es^2 = \sigma_s^2$. Since we have $e(m|\gamma) = \xi\gamma$, where $\xi = \sigma_m^2/(\sigma_m^2 + \sigma_s^2)$, we obtain

$$(25)\ e(m|\alpha, \gamma) = e(m|\gamma) + e(m - e(m|\gamma)|\alpha - e(\alpha|\gamma)) = \xi\gamma + \lambda(\alpha - h_1 - \xi\gamma),$$

where $\lambda = \sigma_m^2\sigma_s^2/\{\sigma_m^2\sigma_u^2 + \sigma_u^2\sigma_s^2 + \sigma_m^2\sigma_s^2\} < \theta$. Unlike α, the public macro information γ is common knowledge. This fact and comparison of (25) with (8) reveal that the case in which γ is available is equivalent to the case of Section 2 except that (1) h_1 is replaced by $h_1 + \xi\gamma$, (2) $\alpha - h_1$ is replaced by $\alpha - h_1 - \xi\gamma$, and (3) θ is replaced by λ. Thus in the symmetric equilibrium we obtain

$$(26)\bar{p} = \frac{1}{c_1}a^* + \frac{1}{c_1}\omega V(\bar{p}|\Omega) + h_1 - \frac{1+c_1k}{c_1}z(\rho_\lambda) + \delta_\lambda(m - \xi\gamma) + \xi\gamma,$$

where $\qquad \delta_\lambda = \rho_\lambda = \dfrac{c_1}{1+c_1k-\{1+c_1(k-1)\}\lambda}.$

The above formula shows that the price level is directly affected by the noisy information γ. However noisy γ is, the firm assumes that other firms use such information because γ is common knowledge. In fact, it can be shown that to provide γ actually reduces social welfare, if (1) σ_s^2 and σ_m^2 are sufficiently large and (2) σ_u^2 is sufficiently small.

On the contrary, the information provision must increase the private gain. If otherwise, the firm could simply ignore such information without incurring any cost. The firm's real benefit under noisy information γ is

$$(27)\ \hat{R} = \exp[\hat{y}(1) + \tfrac{1}{2}\hat{V}(1)] - \exp[(1+c_1)\hat{y}(2) + \tfrac{1}{2}(1+c_1)^2\hat{V}(2) + \Gamma(\rho_\theta)],\ \text{where}$$

$$\hat{y}(1) = \bar{\bar{y}} - (k-1)A + \tfrac{1}{2}[\{1-(k-1)(\rho_\theta+C)\}^2-\{1-(k-1)\rho_\theta\}^2]\sigma_u^2 + \tfrac{1}{2}(k-1)^2D^2\sigma_s^2,$$

$$\hat{y}(2) = \bar{\bar{y}} - kA + \tfrac{1}{2}(1+c_1)[\{1-k(\rho_\theta+C)\}^2-(1-k\rho_\theta)^2]\sigma_u^2 + \tfrac{1}{2}(1+c_1)k^2D^2\sigma_s^2.$$

$$\hat{V}(1) = \{1 - \rho_\theta - (k-1)B\}^2\sigma_m^2,\ \text{and}\ \hat{V}(2) = \{1 - \rho_\theta - kB\}^2\sigma_m^2,\text{in which}$$

$$A = \frac{\omega\rho_\theta^2}{1+c_1k}(\lambda - \theta)\sigma_u^2;\ B = (1 - \frac{c_1}{1+c_1k})\rho_\theta\{\lambda + (1-\lambda)\xi - \theta\};$$

$$C = (1 - \frac{c_1}{1+c_1k})\rho_\theta(\lambda - \theta);\ \text{and}\ D = (1 - \frac{c_1}{1+c_1k})\rho_\theta(1 - \lambda)\xi.$$

It can be shown that $\hat{R} \geq R$. Thus the noise in public information reverses the conclusion in the previous section if σ_s^2 and σ_m^2 are large and σ_u^2 is small.

Table 3 illustrates the effect of real balances and noisy public information. In this table, $c_1 = 0.24$ and $k = 2.67$ as in Table 2. In addition, I use $\sigma_m = 0.05$ and $\sigma_u = \sigma_m$ as a bench mark. Table 2 shows that we have PG = 0.016 and SG/PG = 7.29 in this case. As for ζ, I consider two cases. On the one hand, the ratio of M1 to annual GNP in the United States is about 0.15. This implies $\zeta = 1/(1+0.15) = 0.87$. On the other, the ratio of M2 is about 0.35, implying $\zeta = 0.75$. For the noise in public information, three cases are chosen as illustrative examples: $\sigma_s = (1/10)\sigma_m$, $(1/2)\sigma_m$, and σ_m.

Table 3 shows that the private gain is smaller and the ratio of the private gain to the social gain is larger than the bench mark case. Thus the relaxation of the two assumptions is likely to strengthen the conclusion obtained in the previous section, that the private gain from using public information about money supply is small though its social gain is substantial.

The Optimal Government Policy

The policy discussion in the previous section depends on the assumption of noiseless public macro information. In the following, I show that the conclusion of the previous section still holds in the case of noisy public information.

Suppose that all firms ignore public information γ, and the government decides to control money supply. However, the government has to rely on information γ in controlling money supply. Let m_G be the controlled change in money supply, determined by the government. I consider the following feedback rule:

(28) $$m_G = - g\gamma.$$

Then the total money supply, m_T, consisting of the autonomous change, m, and the controlled change, m_G, is

(29) $$m_T = m + m_G = m - g\gamma.$$

Suppose that the government wants to minimize the variance of m_T. The variance-minimizing g satisfies

$$(30) \qquad g = \sigma_m^2/(\sigma_m^2 + \sigma_s^2) = \xi.$$

Then equilibrium relations in this economy are obtained by replacing m by m_T in the model of Section 2.

Because $g = \xi$, we get $m_T = m - \xi\gamma$. Then it is fairly easy to show that the variance-minimizing monetary policy yields the same real variables (aggregate income and real balances) as in the case in which all firms use information γ.[9] The variance-minimizing policy is superior to simple information provision because it saves the information cost. Thus the conclusion of the previous section, that the government intervention is superior to simple information provision, still holds true under noisy public information.

5. A PERFECTLY COMPETITIVE CASE

In this section, I analyze the case of perfect competition. The main finding is that the private gain is sufficiently large that firms are likely to use public information. This implies that imperfect competition plays a crucial role in making the private gain small in the previous sections.

Consider an economy with homogeneous products but informationally separated markets, which has been extensively investigated in the literature (see Lucas (1973)). Let p_u be the product price in the u-th market, and $\bar{p}$ is the price level. Because of the homogeneity of products, we have $\bar{p} = \bar{p}_u$, where $\bar{p}_u$ is (the log of) the geometric average price. Firms cannot observe $\bar{p}$, though they can observe p_u. Product demand q_u in the u-th market is

$$(31) \qquad q_u = m_u - p_u, \text{ where } m_u = m + u.$$

The term m_u is the total money supply in the u-th market, which consists of the economy-wide disturbance m and the market-specific disturbance u. The stochastic characteristics of m and u are the same as in Section 2. Without loss of generality I assume there is one firm in each market. A price-taking firm maximizes, with respect to q_u,

$$(32) \qquad \hat{E}\,\Pi = \hat{E}\,\exp[p_u - \bar{p}]\exp[q_u] - \exp[(1 + c_1)q_u],$$

where $\hat{E}$ is the expectation operator with respect to the firm's subjective distribution of $\bar{p}$. The firm's information set Ω_c contains p_u. Then the supply of the product in the u-th market is

$$(33) \qquad q_u^{\,s} = \frac{1}{c_1}[- a_c + p_u - e(\bar{p}|\Omega_c)], \text{ where } a_c = \log(c_1+1) - \frac{1}{2}V(\bar{p}|\Omega_c).$$

This is a variant of the Lucas supply function.

Under complete information, we have $e(\bar{p}|\Omega_c) = \bar{p}$ and $V(\bar{p}|\Omega_c) = 0$, so that the equilibrium price level $\bar{p}^*$ and the equilibrium relative price $p_u^* - \bar{p}^*$ are, respectively,

$$(34) \qquad \bar{p}^* = \frac{1}{c_1}\log(c_1+1) + m, \text{ and } p_u^* - \bar{p}^* = \frac{c_1}{1 + c_1}u.$$

Then the firm's ex post real profit $E\,\Pi^*$ under complete information is

$$(35) \qquad E\,\Pi^* = \exp[\tfrac{1}{2}\sigma_u^2 - \frac{1}{c_1}\log(c_1+1)]\cdot\frac{c_1}{1 + c_1},$$

where E is taken with respect to m and u.

Under incomplete information, using the undetermined coefficient method (see APPENDIX), we obtain

$$(36) \qquad e(\bar{p}|\Omega_c) = \frac{1}{c_1}(1 - \theta)a_c + \theta p_u.$$

Then the equilibrium price level $\bar{p}$ and the equilibrium relative price $p_u - \bar{p}$ are

$$(37)\ \bar{p} = \frac{1}{c_1}a_c + \frac{c_1}{1+c_1-\theta}m \text{ and } p_u - \bar{p} = \frac{c_1}{1+c_1-\theta}u, \text{ where } a_c = \log(c_1+1) - \tfrac{1}{2}V(\bar{p}|\Omega_c).$$

Consequently the firm's ex post real profit $E\,\Pi$ under incomplete information is

$$(38) \qquad E\,\Pi = \exp[\frac{1}{2}\{\frac{(1+c_1)(1-\theta)}{1+c_1-\theta}\}^2\{\sigma_m^{\,2} + \sigma_u^{\,2}\} - \frac{1}{c_1}a_c]\cdot\{1 - \exp[-a_c]\},$$

Suppose that perfect information about $\bar{p}$ is now available in the imperfect information case. If this firm is the only firm that uses this perfect information, then formulae in (37) are still valid. Consequently, the ex post real profit is

$$(39) \qquad E\,\hat{\Pi} = \exp[\frac{1}{2}\{\frac{1+c_1}{1+c_1-\theta}\}^2\sigma_u^{\,2} - \frac{1}{c_1}\log(c_1+1)]\cdot\frac{1}{1+c_1}.$$

Let us assume that the ex post real profit of the firm is equal to social welfare, as in Section 3. Then the social gain from using perfect information about $\bar{p}$, SG, is $(E\Pi^* - E\Pi)/E\Pi$, while the private gain PG is $(E\hat{\Pi} - E\Pi)/E\Pi$. Because we obtain from (35) and (39)

$$(40) \qquad E\hat{\Pi}/E\Pi^* = \exp[\frac{1}{2}\{(\frac{1+c_1}{1+c_1-\theta})^2 - 1\}\sigma_u^{\,2}] > 1,$$

the private gain is always <u>larger</u> than the social gain. Thus under perfect competition, the information cost necessary to prevent the firm from using public information is large. Thus the firm is likely to use public information.

The fundamental difference between the monopolistic competition model of Section 3 and the perfect competition model of this section is the role of price level. In the monopolistic competition model, the location of the demand curve determines the firm's profitability. The firm knows all parameters in demand function except for the price level. Thus uncertainty about the price level is the source of uncertainty about the location. If the price level is sticky because of local-global confusion, then uncertainty about the location of the demand curve is reduced and gains from knowing the accurate location decreases. Consequently under monopolistic competition, imperfect information reduces the private gain from obtaining information about the price level.

On the contrary, the relative price determines the firm's profitability in the perfectly competitive model. Local-global confusion makes the relative price $p_u - \bar{p}$ more sensitive to the local condition u under imperfect information than under perfect information (compare (34) with (37)). Thus the relative price is more volatile under the former than the latter. Consequently, under imperfect information, the firm will increase its profits by obtaining accurate information about the relative price. The only way to get such information is to get accurate information about $\bar{p}$. Thus imperfect information increases the private gain from using public information about $\bar{p}$ in a perfectly competitive economy.

6. CONCLUDING REMARKS

This paper has shown that in a imperfectly competitive economy under imperfect information, a private gain from using public information may substantially differ from its social gain. The private gain may be very small, and thus even a small cost of monitoring and assessing such information may effectively prevent the firm from using the information. The expectations of the firm become "irrational" in the sense that the firm does not incorporate all available information. Such irrational expectations result in a large loss in social welfare.

The small-information-costs argument for irrational expectations depends on the near-constant marginal cost of production and a large degree of monopoly power. If marginal cost of production is rapidly increasing and competition is strong, then the private gain is large and close to the social gain. Although recent studies support near-constant marginal costs and a large market power in the framework of bilateral-monopoly labor markets, more research on the microeconomic market structure will be needed in order to assess the practical importance of the argument.

Finally, a remark may be due on the multiplicity of equilibria in the presence of information costs. In this paper, we have investigated the possibility of equilibrium in which all firms do not use public information. However, for a level of information costs producing such equilibrium, there may exist another equilibrium in which all firms use public information. In fact, it is possible to construct a numerical example of such a two-equilibria case in our model. In such a case, the way the economy selects one of the two equilibria becomes important in understanding the dynamic behavior of the economy. It is, however, beyond the scope of this paper, which is bound to be static.

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APPENDIX

Rational Expectations under Incomplete Information

Let the firm assume

$$p_u - \bar{p}_u = \rho u \text{ and } e(\bar{p}|\Omega) = J + K(\alpha - h_1).$$

Under rational expectations, we have $e(m|\Omega) = \theta(\alpha - h_1)$ where $\theta = \sigma_m^2/(\sigma_m^2 + \sigma_u^2)$, and $V(m|\Omega) = E[\{m-e(m|\Omega)\}^2] = \theta\sigma_u^2$. Using these results, we obtain $e(\bar{p}|\Omega)$ and $V(\bar{p}|\Omega)$ in the following way.

First, insert the above formula of $e(\bar{p}|\Omega)$ into the individual optimal price formula (5) and average it over u. Second, substitute the resulting expression into the $\bar{p}$ equation (3). Finally, apply $e(\cdot|\Omega)$ on both sides, and collect terms in order to get the expressions for J and K. The value of ρ is obtained immediately from the resulting price equation. These procedures yield

$$\rho = \rho_\theta;\ J = \frac{1}{c_1}a + h_1 - \frac{1+c_1k}{c_1}z(\rho_\theta);\ \text{and } K = \delta_\theta\theta.$$

As for $V(\bar{p}|\Omega)$, apply $V(\cdot|\Omega)$ on both sides of the $\bar{p}$ equation (3), and substitute the expression of $V(m|\Omega)$ above into the resulting expression. Then we get

$$V(\bar{p}|\Omega) = \delta_\theta^2\theta\sigma_u^2.$$

From these results, it is straightforward to get the the price level (9) in the text.

Private and Social Gains from Using Public information in the Case of $c_1 \to 0$

In the following, I show (21). In this section lim represents the limit when c_1 approaches to zero.

Note that

$$(A1)\ \frac{W^* - W}{W} = \frac{\exp[\bar{\bar{y}}^*]\{1 - \exp[c_1\bar{\bar{y}}^* + \Gamma(\rho^*)]\}}{\exp[\bar{\bar{y}} + \frac{1}{2}V(\bar{y})]\{1 - \exp[c_1\bar{\bar{y}} + \frac{1}{2}c_1(c_1+2)V(\bar{y}) + \Gamma(\rho_\theta)]\}} - 1.$$

Because we have $\lim \rho_\theta = \lim \delta_\theta = 0$, $\lim V(\bar{y}) = \sigma_m^2$, and

$$(A2)\quad \bar{\bar{y}}^* - \bar{\bar{y}} = \frac{\{1+c_1(k-1)\}\{(c_1+2)(k-1)-1\}c_1\theta}{2[1+c_1k - \{1+c_1(k-1)\}\theta]^2}\sigma_u^2$$

$$+ \frac{1}{2}\left[\frac{1+c_1}{1+c_1k} + \frac{1+c_1-\{1+c_1(k-1)\}\theta}{1+c_1k-\{1+c_1(k-1)\}\theta}\right]\frac{\{1+c_1(k-1)\}\theta}{[1+c_1k-\{1+c_1(k-1)\}]}\sigma_u^2,$$

we obtain $\lim [\bar{\bar{y}}^* - \{\bar{\bar{y}} + \frac{1}{2}V(\bar{y})\}] = \frac{1}{2}\sigma_m^2 > 0$, and $\lim \{c_1\bar{\bar{y}} + \frac{1}{2}c_1(c_1+2)V(\bar{y}) + \Gamma(\rho_\theta)\} = \lim \{c_1\bar{\bar{y}}^* + \Gamma(\rho^*)\} = -a^*$. Then we get the first part of (21).

Next consider the private gain from using public macro information. Note that $\hat{R} = \exp[\bar{\bar{y}} + \frac{1}{2}V(y)]\cdot\Delta$, where

$$\Delta = \exp[\frac{k-1}{1+c_1k}\omega\delta_\theta^2\theta\sigma_u^2 + \frac{1}{2}\Phi(c_1,k,\theta)\sigma_u^2 + \frac{1}{2}\{(\frac{1+c_1}{1+c_1k})^2-1\}V(y)]$$

$$- \exp[c_1\bar{\bar{y}}+\frac{(1+c_1)k}{1+c_1k}\omega\delta_\theta^2\theta\sigma_u^2+\frac{1}{2}(1+c_1)^2\Xi(c_1,k,\theta)\sigma_u^2+\frac{1}{2}\{(\frac{1+c_1}{1+c_1k})^2-1\}V(y)+\Gamma(\rho_\theta)].$$

Because $\lim \delta_\theta = \lim \Phi = \lim \Xi = 0$, we obtain $\lim \Delta = 1 - \exp[-a^*]$. Thus we obtain the second part of(21).

Private and Social Gains from Using Public information in the Case of $k\to\infty$.

I show (22) in this section. Hereafter lim represents the limit when k goes to infinity. We obtain $\lim \rho_\theta = 0$; $\lim z(\rho_\theta) = 0$; and

$$\lim \frac{1+c_1k}{c_1} z(\rho_\theta) = \frac{1}{2}\left(\frac{\theta}{1-\theta}\right)^2 \sigma_u^{\,2} > \lim \frac{1+c_1k}{c_1} z(\rho^*) = 0.$$

First, consider the private gain. The above relations imply

$$\text{(A3)} \qquad \lim[\hat{y}(1) + \tfrac{1}{2}\hat{V}(1))] = -\frac{1}{c_1}a^* = \lim \bar{\bar{y}}^*, \text{ and}$$

$$\text{(A4)} \lim[(1+c_1)\hat{y}(2)+\tfrac{1}{2}(1+c_1)^2\hat{V}(2)+\Gamma(\rho_\theta)]\}] = -(1+c_1)\frac{1}{c_1}a^* = \lim[(1+c_1)\bar{\bar{y}}^*+\Gamma(\rho^*)].$$

Therefore we obtain the first part of (22).

Next, I show that there exists a non-negligible social gain, so that our analysis is not void. Using the limiting relations described earlier, we obtain

$$\lim \bar{\bar{y}}^* = \lim \bar{\bar{y}} + \frac{\theta\sigma_u^{\,2}}{2(1-\theta)^2}(c_1 + 2 - \theta) > \lim \bar{\bar{y}},$$

$$\text{(41)} \qquad \lim V(\bar{y}^*) = 0 < \lim V(\bar{y}^*) = \sigma_m^{\,2}, \text{ and}$$

$$\lim \Gamma(\rho^*) = 0 < \lim \Gamma(\rho_\theta) = \frac{1}{2}(1+c_1)c_1\left(\frac{\theta}{1-\theta}\right)^2\sigma_u^{\,2}.$$

Because $\partial W/\partial\bar{\bar{y}} > 0$, $\partial W/\partial V(\bar{y}) < 0$, $\partial W/\partial\Gamma(\rho) < 0$ in the relevant range, we have the second part of (22).

Rational Expectations in the Competitive Case

Let the firm assume

$$e(\bar{p}|\Omega_c) = J + Lp_u.$$

Inserting this into the equilibrium price formula (37), averaging it over all markets, and rearranging terms, we obtain

$$\tau = m + u, \text{ where } \tau = \frac{1}{c_1}[(1 + c_1 - L)p_u - a_c - J].$$

Then we obtain $e(m|\Omega_u) = \theta\tau$ and $V(m|\Omega_u) = \theta\sigma_u^2$. Apply $e(\cdot|\Omega_u)$ to the both sides of (37), substitute $\theta\tau$ for $e(m|\Omega_u)$, and collect terms in the resulting expression to get the expressions of J and L. Then we obtain the result in the text.

NOTES

1. In the symmetric equilibrium, we obtain $(1-k)\bar{p} = \log E\exp[u+(1-k)p_u]$ and $p_u-\bar{p}_u = \rho u$ for some ρ. Substituting the latter equation into the former, and using the property of log-normal distributions, we obtain (3).

2. From the individual demand function, we obtain the labor demand of the firm of type u such as $\ell_u = (1/\phi)[-k(p_u - \bar{p}) + \bar{y} + u]$, where $\ell_u = \log L_u$. Substituting this equation, $\bar{p} = \bar{p}_u - z(\rho)$, and $p_u - \bar{p}_u = \rho u$ into the definition of the aggregate disutility of labor, and using the property of log-normal distributions, we obtain (11).

3. Incomplete information also introduces uncertainty about the price level. Such uncertainty reduces the long-run level of production in our model.

4. So long as $\rho < k - 1$. This condition holds true except for a large k.

5. This figure is considerably smaller than the one implied from the literature of labor supply. Empirical studies of labor supply typically find the elasticity of labor supply about 0.15 (Killingsworth (1983)), which implies the elasticity of marginal disutility is equal to 6.7.

This difference, however, may be explained by the nature of (implicit) contracts in a (short-run) bilateral monopoly relation in labor markets. For example, suppose that labor supply (the supply of labor hours) of the worker is completely inelastic at some level. Even in this case contract theory implies that the level of labor input varies as demand fluctuates if the (implicit) contract involves the possibility of layoffs, so long as there exist non-trivial unemployment compensations. Although the supply of labor hours for each worker is completely inelastic, the supply of labor hours from the firm's labor pool is elastic. Not the former but the latter determines the level of output.

6. Weitzman (1985) and Hall (1986) argue that this is a reasonable assumption in the short run.

7. In this simple model, the consumer gets the beginning-of-the-period money balances through the government's transfer.

8. Note that the price level is different. However, this does not make any difference in our static model.

9. The only difference is the price level. In the equilibrium using public information the price level depends on ε_Y, while in the equilibrium with the minimum-variance monetary policy it is not. However, this does not change the level of welfare.

Table 1

Microfoundation: Summary of the Model

A. DISTURBANCES

$N(0, \sigma)$ represents a normal distribution with mean zero and variance σ.

(1) Money supply M: $m = \log M \sim N(0, \sigma_m^2)$, where $g(m)$ is its density.

(2) Preference disturbance e^u: $u \sim N(0, \sigma_u^2)$, where $f(u)$ is its density.

B. REPRESENTATIVE CONSUMER-WORKER

(1) Utility function: $\Psi = \chi(\tilde{M}/\bar{P})^{1-\zeta}(\bar{Y})^{\zeta} - D$, where $\chi \equiv \{\zeta^{\zeta}(1-\zeta)^{(1-\zeta)}\}^{-1}$ is the normalization factor; $\tilde{M}$ the desired money holdings;

$\bar{Y} \equiv [\int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)}\{e^u\}^{1/k} Q_{iu}^{(k-1)/k}\, di du]^{k/(k-1)}$ the aggregate consumption;

$\bar{P} = [\int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)}\{e^u\}P_{iu}^{1-k}\, di du]^{1/(1-k)}$ the price index associated with $\bar{Y}$;

and $D = [\int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)} L_{iu}^{\mu}\, di du]$ the aggregate disutility of labor;

in which Q_{iu} and P_{iu} are the consumption and the price of the i-th product of type u; and L_{iu} is the labor supply to the firm producing the i-th product of type u. ζ and k satisfy $1 > \zeta > 0$, and $k > 2$.

(2) Budget : $\int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)}P_{iu}Q_{iu}\, di du + \tilde{M} = \int_{u=-\infty}^{u=+\infty}\int_{i=0}^{i=f(u)}\{\Lambda_{iu} + \Pi_{iu}\}di du + M$, in which Λ_{iu} and Π_{iu} are wage payments and dividends from the firm producing the i-th product of type u.

(3) Problem: Max Ψ with respect to Q_{iu} subject to the budget.

C. FIRM

(1) Objective function: $R \equiv (\Pi_{iu}/\bar{P}) + \{(\Lambda_{iu}/\bar{P}) - L_{iu}^{\mu}\} = (P_{iu}Q_{iu}/\bar{P}) - L_{iu}^{\mu}$.

(2) Production function: $Q_{iu} = L_{iu}^{\phi}$,

(3) Problem: Max R with respect to P_{iu} subject to the production function, the demand function, and informational constraints (described in the text).

D. SYMMETRIC EQUILIBRIUM

(1) Monetary Equilibrium: $M = \tilde{M}$.

(2) Symmetry: $P_{iu} = P_{ju} = P_u$ and $Q_{iu} = Q_{ju} = Q_u$ for all $i \neq j$.

Table 2

Private Gain (PG) and Social Gain (SG)

from Using Public Macro Information

When (1) Private Benefit Coincides with Social Welfare

and (2) Public Macro Information Is Accurate

σ_m \ σ_u/σ_m [a]	1/2	1	5
0.05	PG [b] = 0.021 SG/PG [b] = 5.37	PG = 0.016 SG/PG = 7.29	PG = 0.011 SG/PG = 10.24
0.2	PG = 0.008 SG/PG = 5.41	PG = 0.006 SG/PG = 7.35	PG = 0.004 SG/PG = 10.32

Notes:

[a] σ_m and σ_u are, respectively, the standard deviation of the monetary disturbance and that of firm-specific demand disturbance.

[b] PG is the percentage increase in the firm's real benefit, and SG is the percentage increase in social welfare.

Table 3

Effects of Utility from Real Balances and Noise in Public Macro Information

$\zeta \setminus \sigma_s/\sigma_m$ [a]	1/10	1/2	1
0.87 [c]	PG [b] = 0.016	PG = 0.011	PG = 0.005
	SG/PG [b] = 9.60	SG/PG = 11.51	SG/PG = 14.52
0.75 [d]	PG = 0.016	PG = 0.011	PG = 0.005
	SG/PG = 12.42	SG/PG = 14.89	SG/PG = 18.79

Notes:

[a] σ_s is the standard deviation of the measurement error in the announced money supply, and σ_m is the standard deviation of the true money supply.

[b] PG is the percentage increase in the firm's real benefit, and SG is the percentage increase in social welfare.

[c] The value of ζ corresponding to M1/GNP.

[d] The value of ζ corresponding to M2/GNP.